Diseases of Fresh-Water Fish

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I. Introduction

Like other animals, fish can be subject to disease. From the viewpoint of fish as food, fish diseases are important for two main reasons: (1) the number of fish available for consumption is reduced; (2) the palatability of diseased fish may be impaired, or they may look unsightly, both conditions making them unacceptable for human consumption. Big economic losses may result from epidemics, especially if they occur in fish-breeding ponds. The protozoan *Ichthyophthirius multifiliis*, causing "white spot" disease, has a particularly bad reputation in this respect; it occurs all over the world.

Fish diseases may be due to parasitic or nonparasitic causes, the former being the most numerous and, from both a pathological and economic viewpoint, the most important.

II. Nonparasitic Affections

A. DISORDERS DUE TO MALNUTRITION

1. Avitaminoses

It has been demonstrated that for fish nutrition a number of vitamins, e.g. thiamine, riboflavin, pantothenic acid, inositol, folic acid, choline,

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biotin, and pyridoxine, are necessary (well reviewed by Halver, 1953). Vitamin requirements may vary among different species of fish and depend on environmental conditions. Although no definite conclusions could be obtained from feeding experiments with respect to vitamins K, B₁₂, and E, definite deficiency syndromes for these vitamins could be produced by treatments with the antibiotic Aureomycin, which affects the intestinal flora. Curiously, the related compound chloramphenicol (Chloromycetin) does not produce avitaminoses and is therefore preferred for treatment of bacterial infections in fish. If Aureomycin is incorporated in fish food, as is sometimes done in order to increase the growth rate, vitamins E, K, B₁₂, and folic acid should also be included in relatively large amounts.

Avitaminoses may also play a role in infectious diseases by lowering the resistance to bacterial infections. Folic acid deficiency lowers resistance to myxobacterial infections, whereas lack of inositol and biotin increase susceptibility to fin rot and blue slime patch disease, respectively (Halver, 1953).

2. Nonspecific Affections of Internal Organs

Inflammation of the stomach, characterized by a reddening of the mucous lining, may result from excessive amounts of salt in the food. It may also be due to incorrect feeding. In fish breeding, it is more often observed in carnivorous fish, such as trout, than in omnivorous species (Schäperclaus, 1954). Healthy fish intestines are whitish or pink, making the red color a characteristic feature. Frequently a bloody, puslike liquid is present inside the inflamed intestine, and bloody or yellowish-colored slimy excreta are produced. Whether palatability of the fish will be impaired depends on the nature of the inappropriate food: tainted meat and rancid fats may contain substances that get into the flesh of the fish consuming such feed, thus spoiling its good taste for human consumption. Further conditions related to malnutrition are fatty degeneration of the internal organs, catarrh of the intestine, and its opposite, constipation.

As will be mentioned later, there is the possibility that a ravaging trout disease, causing liver degeneration and kidney swellings, should be classified as a deficiency disease (see Section III, C).

B. INTOXICATIONS

Many adverse conditions of a chemical nature can affect the health of fish. Extreme acidity or alkalinity of the water at first affects resistance to other diseases, but then exerts a direct specific action. The normal pH range differs greatly (pH 5.5–8); European waters generally have a pH 7–8, whereas in the tropics slightly acid reactions seem to be common.
Under aquarium conditions, it has been found that the breeding capacity of several species of fish depends on a suitable pH range of the water. Whereas lack of oxygen in crowded ponds may often cause heavy losses, the reverse condition of supersaturation with oxygen may also be dangerous by causing gas embolism. In running stream waters this will not occur. Carbon dioxide poisoning can occur only at rather low pH values and is not related to conditions of lack of oxygen, as shown by Van Duijn (1952), thus contradicting assertions by Atz (1950) and Klee (1951).

Many industrial waste disposals contain heavy fish poisons, such as phenolic and chlorine compounds, arsenicals, and heavy metal compounds, which are a real threat to fish population in industrial countries like those of Western Europe.

Intoxications can, however, result also from poisonous substances produced by metabolic processes. Among them must be mentioned ammonia, sulfuretted hydrogen, and nitrites, all of which result from microbial breakdown of proteins and may exceed critical concentrations if anaerobic conditions become prevalent in the water bottom; under normal aerobiosis the substances are converted into nontoxic compounds. Some microorganisms, such as certain unicellular algae, may produce substances toxic to fish. The palatability of the fish may be affected by such substances and also by several other compounds that in themselves cannot be regarded as toxic, such as certain highly unsaturated fatty acids, present in blue-green algae (Oscillatoria).

Cases are also known where through a waterbloom, ammonia is released from an excess of available ammonium salts, thus reaching toxic concentrations, with a mass death of fish ensuing. This is reported from Germany, where sewage-treatment plants have released water with a high mineral content (Schäperclaus, 1952-1953). Chlorella and Ankistrodesmus are main constituents of such blooms.

C. TUMORS

Several types of benign, as well as malignant, tumors occur in fish. Some are listed below:

- adenoma
- carcino ma
- epithelioma
- fibroma
- fibrosarcoma
- granuloma
- haematoma
- leiomyoma
- lipoma
- lymphosarcoma
- melanoma
- myxoma
- neurilemmoma
- neurofibroma
- rhabdomyoma
- teratoma
- neuron broma
- rhabdomyoma
- teratoma

Numerous reviews of tumors observed in fish are available (Hofer, 1904; Plehn, 1924; Schlumberger and Lucke, 1948; Nigrelli, 1953; Schäperclaus, 1954b). A comprehensive treatise was also published in 1954-1955 by Reichenbach-Klinke.
While carcinomas are not uncommon in fish, sarcomas seem to occur but rarely; a true spindle-cell sarcoma has been reported by Van Duijn (1957). Tumors have no other effect than rendering food fish unsightly and less palatable. Since tumors occur only in isolated cases and in single specimens, their economic importance is minor.

A new disease in eels was reported for the first time in 1948 in the southern Baltic and has been given the descriptive designation of "cauliflower disease." Its syndrome and causative relationships are discussed in Chapter 15 of this volume.

III. Diseases of Parasitic Origin

A. Fungus Infections (Mycoses)

Molds of the family Saprolegniaceae may attack the skin, and sometimes the gills and eyes, of fish in which the resistance of these organs has been weakened by injury, by other parasites, or such adverse conditions as an abnormal pH of the water. The infection is characterized by the growth of thin threads of dirty-white or grayish color from the infected parts, resembling tufts of cotton wool if growth of hyphae is abundant. Valuable fish can be cured by suitable treatments with chemicals; phenoxethol and some of its derivatives, introduced by Ian M. Rankin, at present may be regarded as the most suitable remedies. For a discussion of alternative treatments, reference is made to Van Duijn (1956).

While the Saprolegniaceae are mainly secondary invaders, other fungi are encountered which are much more dangerous. Branchiomyces sanguinis Plehn and B. demigrans Wundsch, belonging to the Phycomycetes—subclass Archimycetes—cause gill rot and may readily kill fish. High temperatures and the presence of much decaying organic matter in the water are conducive to the development of these infections. This disease is a major trouble in the carp hatcheries of the Ukraine (Dogel, 1957).

To the same subclass of fungi belong the Ichthyophonus parasites I. hoferi, I. intestinalis, and I. lotae (family Chytridiaceae, order Chytridiales). In living fish, symptoms are not distinctive: infected fish swim with sluggish movements, their bellies grow thin and show a concave contour. Finally, the fishes lose equilibrium and sometimes, if the parasites have penetrated into the brain, they make tumbling movements before they die. The parasites are found in internal organs, where they produce whitish-gray granular cysts located between tissues, or yellowish-to-brown, and even black-colored, cysts inside these organs themselves. These cysts may develop an amoeboid stage which periodically moves out and further penetrates additional organs. Generally, the course
of the disease is slow; it may take months or even years before an infected fish dies. Infection takes place by transmission of cysts which, after having entered the water, are eaten by other fish. Infected fish are unpalatable, but they are no threat to human health if consumed. Extensive discussions on this important disease have been presented by Reichenbach-Klinke (1954), who proposed a change of the generic name, and by Schäperclaus (1954b).

B. BACTERIAL INFECTIONS

Most of the bacteria infecting fish can harm these only if they are injured or weakened. Occasionally, bacteria possessing a higher degree of pathogenicity may attack completely healthy fishes. With regard to the identification and nomenclature of bacteria pathogenic to fish, considerable confusion exists. This is due partially to deficiencies in the descriptions of bacteria isolated from diseased fish. On the other hand, there is some difficulty in obtaining reliable experimental material from animals that are surrounded by a medium in which all kinds of bacteria closely related to pathogens are present. Furthermore, experimental animals—required for proving the pathogenicity of an isolated strain of bacteria—cannot be kept under aseptic conditions. Consequently, knowledge is still scanty and often controversial.

Among the infectious diseases of which the bacterial aetiology seems to be well established are the following:

Furunculosis of salmonids is caused by *Aeromonas* (formerly *Bacterium*) *salmonicida*. Symptoms are heavy inflammation of the intestine and sometimes of the peritoneum, followed by haemorrhages in the muscles and the production of swellings or boils (furuncles) at the surface, usually on the sides of the body. The disease is highly contagious and requires special measures for control. Sulfonamides, chloramphenicol, (Chloromycetin) and oxytetracycline (Terramycin) have been found effective (see review by Snieszko, 1953; also see McCraw, 1952).

Red pest of carp and tench (Latin: *Purpura cyprinorum*) is characterized by a red coloration of the skin of the belly and of the fins, while necrosis and haemorrhages occur in the gills. Causative organisms may be special strains of *Pseudomonas putida*, sometimes distinguished as *forma cyprinicida* (formerly *Bacterium cyprinicida* Plehn) and *Pseudomonas putida forma Davidi*, and in addition *Pseudomonas plehniae*.

Red pest of eels (Latin: *Pestis rubra anguillarum*) is caused by *Vibrio anguillarum*. It also infects perch and pike, in which scale protrusion may be one of the symptoms. It occurs, however, only in waters with a relatively high salt content, at least 0.25%. The mortality rate from this disease is heavy. It is recorded that 200 years ago it occurred in the old
and famous eel-rearing establishment at Comacchis, not far from Ravenna. Since then it has appeared on the Dalmatian coast, also on the Baltic coast of Denmark and Sweden, and in reservoirs on the Danish coast (Rushton, 1957). This disease was thoroughly investigated by an Italian biologist, Inghilleri, as early as 1901, and its etiology clarified then.

Special strains of ordinary water bacteria may have pathogenic effects on fish. Among them is *Pseudomonas fluorescens*, which has been isolated as the causative agent of red pest and ulcerating diseases in eels and other fish (Schäperclus, 1926). An epidemic caused by this organism, restricted to labyrinth fishes in a mixed population, has been described by Van Duijn (1938, 1956). Special strains of *Aeromonas* (formerly *Pseudomonas* or *Chromobacterium*) *punctata* have proven pathogenic to fish. Their importance has been especially stressed by Schäperclus (1930, 1934), who also tried to identify numerous other bacteria described previously with his isolations. With regard to modern knowledge of bacterial variability and genetics, it must be considered doubtful whether distinguishing such strains as special separate varieties (*forma ascitae*, *f. sacrowiensis*, *f. pellis*, and even more) could reasonably be maintained.

Other strains of *A. punctata* have been isolated from several diseases in which ulcers and botches are produced. The pathogenicity of several strains of this species has been established experimentally.

An example of the considerable confusion as to the identity of bacteria isolated from diseased fish is the fact that whereas Schäperclus (1930, 1954a) tried to identify every possible isolation with *Pseudomonas punctata*, Snieszko (cited by Griffin, 1953) advocates combining *Pseudomonas punctata*, *P. hydrophila*, *P. granulata*, *P. hirudinis*, *Proteus hydrophilus*, *P. melanovogenes*, *Aerobacter liquefaciens*, and others, all into one species which he named *Aeromonas liquefaciens*. Since in this list there are bacteria which have only slight sugar-fermenting powers and may show fluorescence (*P. granulata*), this combination does not seem justified, except perhaps for a few individual cases. At least the “Proteus” species have been wrongly named, since these have polar flagellation, as in the *Pseudomonas—aeromonas* group, instead of a peritrich one, characteristic of the genus *Proteus*. In Soviet publications this very same organism is given the name *Achromobacter punctatum*.

The infectious swelling of the belly (ascites) is undoubtedly the most serious disease hampering present-day carp cultivation on the European continent, chiefly in the Soviet Union, Poland, and Germany. This disease is frequently termed “dropsy.” In spite of a tremendous amount of research, and numerous devices and chemicals with which to combat this disease, it still is raging and constantly causing substantial losses. Various subtypes have been described, but Schäperclus considers all of them
induced by *A. punctata*. In recent years, the thought has become more prevalent that this organism could be a secondary invader only. Certain evidence points to the possibility that the primary infection is of a viral nature—see further Roegner-Aust and Schleich (1951) and Roegner-Aust (1952). This is strongly advocated by Soviet and Rumanian fish pathologists, while Polish studies support the bacterial concept of this disease (Kocylowski, 1958). Flemming (1958) reports that carp when starved, which frequently happens after the winter period, have a sharply reduced protein level in the blood and are particularly susceptible to dropsy attacks. Comprehensive reviews of all aspects of this important disease were published in 1953 by Wunder and Dombrowski and in 1959 by Gontjarov.

Schäperclaus (1954a) published substantial evidence for the existence of specific bacteriophages active against dropsy. By building up active phages in natural waters, it appears possible to check this disease.

Examples of bacteria representing other groups are *Haemophilus piscium*, isolated from intestinal wounds, blood, and kidneys of fingerling brook trout suffering from "ulcer disease," and some acid-fast bacteria causing fish tuberculosis.

*Mycobacterium piscium* and *M. platypoecilus* have been isolated from fresh-water fishes, and *M. marinum* from marine fish. They produce tiny knots (cysts) in the internal organs and may also affect the skin, fins, eyes, and skeleton. Fish tuberculosis may occur as epidemics and cause heavy losses. The causative bacteria are harmless to warm-blooded animals and man [see review by Reichenbach-Klinke (1954-1955) and also Van Duijn (1961)].

One noteworthy case of tuberculosis in salmon was reported in 1958 (Wood and Ordal) from the North Pacific region of the United States. Extremely high incidences were encountered in salmon known to be of hatchery origin—in some cases attaining 100%. The disease was absent in the silver and chum salmon known to be the product of natural spawning. The most likely method of dissemination was considered to be the practice of feeding untreated salmon carcasses and viscera to young fish in hatcheries. Baker and Hagan (1942) showed that the etiological agent of tuberculosis in the Mexican platyfish was highly pathogenic when offered in the feed. Once the disease becomes sufficiently advanced, the bacteria are readily transmitted in a crowded hatchery pond.

A myxobacterium, *Chondrococcus columnaris*, causes "cotton wool disease," sometimes wrongly referred to as "mouth fungus"; it attacks the mouth, skin, and gills. Another important complaint due to bacterial infection is tail- and finrot; although several isolations have been made, it is not yet possible to ascribe this condition to a single definite species.
For a more general orientation on bacterial infections and their control, one should consult Griffin (1953) and Snieszko (1953).

C. Virus Infections

Thus far, only a limited number of fish diseases could be attributed to virus agents. It may, however, be expected that their number will increase markedly as soon as expert virologists become more interested in the field of fish disease. The most recent review is that by Watson in 1953.

Pox disease—Latin name: Epithelioma papulosum—is characterized by the occurrence of whitish, opaque spots on a thickened epidermis. It occurs mainly in common carp and Prussian carp, but has also been observed in other fish, including some outside the Cyprinid family, such as smelt and the European pike perch (Lucioperca sandra).

A new trout disease which has become a serious problem in the 1950's and is somewhat of a riddle is characterized by a swelling of the kidneys and a degeneration of the liver. It has been given numerous names—INuL (an abbreviation of the German description of the disease), Egtved disease (Danish designation), etc. Two schools of thought have developed as to the character of the disease, one maintaining it is an infectious virus disease, the other group that it is due to nutritional deficiencies (lack of vitamins B and E). Some research workers take the middle way and acknowledge the possibility that nutritional disorders reduce the resistance to infection and that infection increases the need for certain nutrients (Faktorovich, 1959). A comprehensive review of these controversies and the present knowledge on this matter recently became available (Mattheis, 1960).

Of considerable interest is the recent West German announcement that the Lake Research Institute in Langenargen succeeded in measuring the size of the responsible virus (Annual Report, 1959).

Infectious dropsy may be caused by a primary virus infection, generally complicated by secondary invasion of Aeromonas punctata or Pseudomonas granulata (Brunner and Striegel, 1952), or perhaps caused by these bacteria alone, as advocated by Schäperclaus (1930, 1954b).

D. Unicellular Algae

Some dinoflagellates may cause epidemical infections in fish. Oodinium limneticum is the causative organism of the velvet, rust, or gold-dust disease, in which the skin of the fish looks like a surface dusted with powdered sulfur or with talcum powder of a dark shade. The “dust” shows a pale yellowish color. It may move around on the skin surface. The infection may also spread to the gills. A related species, O. ocellatum
Brown (*Branchiophilis maris* Schäperclaus) attacks the gills of coral fishes (marine).

*Chlorochytrium pisciolens*, belonging to the Protococcaceae, may cause inflammations of the epithelium of the skin and the gills in carp, tench, and lake perch.

Other unicellular algae affecting fish are *Ichthyochytrium vulgare* and *Mucophilus cyprini*; formerly these were regarded as members of the *Chytridiaceae* (class Phycomycetes) of the fungi.

**E. PROTOZOA**

1. **Ciliata**

   The most important parasite from this group is, no doubt, *Ichthyophthirius multifiliis*, causing white spot disease or "Ich." The causative organism is nearly sphere-shaped, holotrich, and contains a horseshoe-shaped nucleus. The parasite penetrates into the epidermis, which reacts by augmentation of the epithelial cells so that the latter is covered by a layer of tissue, appearing as white spots. Periodically, ripe parasites leave the fish for reproduction inside a cyst, where one parasite produces from 500 to 1200 young, which swarm out into the water; thus, infection spreads rapidly. Heavy losses may result from this disease. The biology of this parasite has been studied extensively by Buschkiel (1936). In the postwar period, the greatest losses in Soviet fish cultivation, particularly that of carp and trout, were inflicted through this ciliate (Bauer, 1958b). Owing to these circumstances this invading disease has been subject to extensive research (Bauer, 1958b). Through preventive measures and the use of curing chemicals, great improvements have been attained in both White Russia and other parts of the Soviet Union, and the disease is receding (Bauer, 1958a, b).

   *Chilodonella* (formerly *Chilodon*) *cyprini* and *C. hexasticha*, belonging to the order Heterotricha, and *Cyclochaete domerguei*, of the order Peritricha, cause epidemics in which the symptom is sliminess of the skin.

2. **Mastigophora**

   *Costia necatrix* (subclass Zoomastigina) causes sliminess of the skin, similar to that produced by *Chilodonella* or *Cyclochaete*.

   *Octomitus intestinalis* and other *Octomitus* species occur as parasites in the intestine and/or the stomach and gall bladder of different fish. Symptoms consist of anomalous swimming behavior (staggering movement and spasmodic dippings of the anal fin) and emaciation resembling
that occurring in *Ichthyophonus* infections. The parasites have an oval body with two groups of three short swimming flagella at the obtuse end and two longer steering flagella at the opposite end.

Sleeping sickness in fish is caused by several *Trypanoplasma* and *Trypanosoma* species, the former being the more common causative agents. *Trypanoplasma* differs from *Trypanosoma* in possessing two flagella situated at opposite ends of the body.

### 3. Sporozoa

A large number of infectious diseases in fish are caused by Sporozoa, most of them belonging to the subclass Neosporidia, order Cnidosporidia. A smaller number belong to the Telosporidia, order Coccidiomorpha. A survey is given by Van Duijn (1953, 1956); for an extensive treatment of this group, reference is made to Schäperclaus (1954b).

All sporozoa in fish are found in the internal organs, where many species produce cysts, which are often readily recognizable with the unaided eye as whitish knots. Sometimes "yellow bodies" are produced from necrotic tissue cells. These occur most abundantly in intestinal coccidiosis, where they are often accompanied by black pigment granules. In several sporozoan infections, knots, pimples, bumps, or boils are produced in the skin, the fins, and/or the gills. Some of the parasites found in knot or pimple disease (Latin name: *morbus nodulosus*) are *Myxobolus exigus*, *M. dispar*, *M. oviformis*, *Glugea anomala*, and several *Henneguya* species. Knots at the gills are produced by several species of the genera *Myxobolus*, *Lentospora*, *Henneguya*, and *Thelohanellus*.

*Myxobolus pfeifferi* is the cause of boil disease in barbel. Boil diseases in Coregonidae and whitefish are produced by *Henneguya zschokkei*, *Myxobolus piriformis*, and *M. notatus*. *Glugea hertwigi* is the causative organism of a disease of smelt in which boils occur, not only in the skin, but also inside the body cavity.

One of the most important sporozoan diseases is the tumbling sickness of young trout (*Salmo fario*, *S. lacustris*, *S. irideus*, and related species), which is due to *Lentospora cerebralis*. This parasite occurs in the nervous system and the auditory organ, while they penetrate into the cartilage, too, thus preventing normal ossification and producing skeletal deformities. Affected fish lose their sense of balance and turn around in an awkward manner; while the position of the longitudinal axis of the body may be maintained, the body is turned around this axis over 180 or even 360 degrees some ten or twenty times before the fish is exhausted and takes some rest at the bottom of the water. This anomalous behavior occurs as sudden outbursts, alternating with periods of normal swimming. Tumbling movements first appear 40–60 days after the infection.
Diseased fish either die or heal spontaneously; in the latter case, they may remain crippled for life, or they may recover without external symptoms. In both cases they may remain carriers of living spores and spread the disease. Therefore, all such fish must be destroyed. Sanitation of infected ponds is performed by strewing 0.5–1 kg. of calcium cyanamide per square meter bottom area after draining off the water, to be added in two portions, the first at the end of November and the second half at the end of March. Six weeks after the second treatment the ponds may be filled again and put into use if the pH of the water is correct; otherwise, a change of water before setting fish may be required. This treatment was originated by E. Tack (1951) and is strongly recommended by Schäperclaus (1954b). The method is also valuable for disinfection in case of other infectious diseases.

F. Metazoa

1. Crustacean Parasites

All crustacean parasites of fish belong to the class Copepoda. The subclass Branchiura contains the well-known fish lice, *Argulus foliaceus*, *A. coregoni* Thorell (*A. phoxini* Leydig), and *A. pellucidus* Wagler (*A. viridis* Nettovich). These parasites have a flattened, leaflike shape and reach a length of 3 to 13 mm. A few specimens on a big fish do not do much harm, but sometimes they may appear in large numbers on one single fish. They are typical skin parasites and may also act as transmitters of bacterial infections from fish to fish. Thus, it has been experimentally established that the carp louse (*Argulus spp.*), if infected, conveys the dropsy agent to the host (Stammer, 1959-1960).

A large number of fish parasites are found in the subclass Eucopepoda. Members of the family Ergasilidae show some resemblance to the well-known fish food animal *Cyclops*; the parasitic genera are *Ergasilus* and *Thersitina*. They are mainly parasites of the gills, where they feed on epithelium and slime cells. Other gill parasites are found in the families Caligidae, which have a flat body, and Chondracanthidae, the latter still showing some morphological resemblance to the cyclopids. Further families of fish parasites are the Dichelestidae, Philichthyidae, Lernaeidae, Lernaeopodidae, and Sphyriidae.

The genus *Lamproglena* Nordmann 1832, is parasitic on the gills of various fresh-water fishes in Europe, Egypt, West Rhodesia, the Belgian Congo, French Sudan, the Soviet Union, Japan, China, and Thailand; it contains 16 recognized species (Humes, 1956). Best known are the parasites *Lernaea* (formerly *Lernaeocera*) *cyprinacea*, *L. esocina*, and *L. phoxinaceae*, occurring on and in the skin. They are often popularly
called “anchor worms,” which, of course, is biologically wrong, but at least gives a really good impression of the attachment organ and the slender, sausage-like shape of the body of the parasitizing females. Egg sacs are carried at the end of the body, as in Cyclops. Males do not parasitize fish. The females may reach a length of about 20 mm., not including appendages.

A review of parasitic Crustacea is given by Schäperclaus (1954b), while the old review by Hofer (1904) is still useful with some minor changes of nomenclature.

2. Worm Infections

Worms, which were once put together in one single phylum, are now distributed over a number of separate phyla of the animal kingdom. Some of these contain a large number of fish parasites.

a. Platyhelminthes

Fish parasites are found in the classes Trematoda and Cestoda. Important external parasites of the Trematoda are found in the orders Digenea and Monogenea.

Yellow grubs are larval stages of the flukes Clinostomum complanatum or C. marginatum, belonging to the Digenea. They produce small, cream-colored, oval cysts on the body, head, and fins. The adult parasites live in the throat and mouth of bitterns, herons, or other fish-eating water birds. Eggs are deposited in the water with the excreta of the birds, where they hatch to miracidia. These infect water snails, where they change into sporocysts that produce rediae. The rediae form daughter rediae, which produce free-swimming cercariae which infect fish and develop into metacercariae. If the infected fish is eaten by a bird, the metacercariae develop into adult parasites and the cycle may start anew.

Black cysts in the skin are produced by the larvae of Neodiplostomum cuticola and related species. These have a life cycle similar to that of the yellow grubs.

In the same order a number of worms are found that in the adult stage live in the bile ducts and pancreatic ducts of cats, dogs, and human beings. The cat liver fluke Opistorchis felineus was found in all cats in the region of the Kurische Haff (Germany) in 1929, and in 1931 in some villages it was found in 6% of the inhabitants, as mentioned by Schäperclaus (1954b) (see also Chapter 1). It is very common in five major food fishes of the Dnieper, according to a recent study (Bliznjok, 1960). Opistorchiasis was encountered in 16% of 90 infected patients in a hospital in the upper reaches of the Irtysh River. The presence of the metacercariae of O. felineus was established in 55% of the ide, 49% of the
whitefish, 45% of the roach, 41% of the tench, and 7% of the carp in Lake Faysan and that section of the Irtysh fed by this lake. All the patients were inhabitants of this area.

Getsevichynte (1958) recently made a renewed study in the lagoons of the Kurische Haff (Kurkij Zaliv), and could confirm the heavy worm infestation; no less than 129 species (49 trematodes, 16 cestodes, 10 nematodes, 4 acanthocephalids, etc.) were found in 424 fish.

The eggs of this worm are taken in by snails of the genus Bithynia, where they develop into cercariae that infect whitefish (Leuciscus) in which they live in the muscles. Human beings are infected if they eat such fish without proper heat treatment (cooking or frying). Related genera of these worms are Haplorchis, Metorchis, Pseudoamphistomum, and Pachycreta.

Fresh-water mullets are strongly incriminated as a vector for transferring various trematodes to man in Egypt (Fahmy and Selim, 1959-1960), as well as in China, the Philippines, and Hawaii (Martin, 1958). Most fresh-water fishes in the Lucknow region of northern India carry heavy infections of monogenetic trematodes on their gills (Jain, 1958). In Egypt, dogs acquire the infection primarily from the fish they are fed; man also is frequently infected (Fahmy and Selim, 1959-1960).

The eel seems to be immune to the trematode Crepidostomum spp., while brown trout is most susceptible. The parr is partially resistant. These are conclusions from recent studies in Welsh rivers (Thomas, 1958).

Flukes, not having such an intricate life cycle and living on the fish as adults, are found in the superfamily Gyrodactyloidae, and belong to the order Monogenea (the yellow grubs belong to the Digenea). The better-known genera are Gyrodactylus, mainly a skin parasite, and Dactylogyrus, Neodactylogyrus, and Ancyrocephalus, all three primarily infecting the gills and being dangerous. For a thorough treatment of their biology, the reader is referred to Dawes (1946). The most obvious symptoms are fading of colors, sliminess of the skin, folded fins, increased breathing frequency, with the gill coverings stretched open and the gills expanded and very pale. The degree of these symptoms varies with the main site of the infection. A sure diagnosis depends on microscopic examination of a smear of the slime from the skin and the gills.

Other Trematoda are parasitic in the internal organs of fish; most of these belong to the genus Distomum and have a life cycle including stages in mussels and snails.

Tapeworms (Cestoda) also have an intricate life cycle with change of hosts. They may be divided into three groups, one in which the larval stage occurs in a lower food animal eaten by the fish that is the final
host, another in which the larvae live in the bellies of one species of fish and the adults in another one, which feeds on the former, and the third group comprising worms with a multiple change of hosts, the final one being a mammal. Common examples of the first group are the clove worm, Caryophyllaeus laticeps, with larvae in Tubifex, and Proteocephalus (Ichthyotaenia) species with larvae in Daphnia and Cyclops; further, the very large tapeworm Ligula simplissima (specimens up to 7 feet in length have been found), whose larvae live in Diaptomus.

The most common representative of the second group is Triaenophorus nodulosus. The adult worms are most often found in pike, and the first larval stage lives in Cyclops.

From a hygienic point of view, the third group is the most important, since to this one belongs the dangerous tapeworm Diphyllobothrium latum (formerly Dibothriocephalus = Bothriocephalus latus). The adult worm may live in the human intestine, where it reaches an average length of 8 to 10 meters, while some specimens up to 17 meters long have been found. The eggs leave the human body with the faeces. If they enter any water, they develop into free-swimming, ciliated coracidium larvae. If these are eaten by a Cyclops, they develop into procercoid larvae of about 0.5 mm. maximum length. If the Cyclops is eaten by a fish, the procercoid develops into the last larval stage, the plerocercoid, situated in the interstitial space of the muscles or the liver and other intestinal organs of fish. The most common fish hosts in Europe are eel, northern pike, lake perch, burbot, lake trout, pope, or eelpout. The chars frequently convey this infestant; so does the grayling. In North America, it is found in the northern pike, walleye, sauger, yellow perch, and in the trout Oncorhynchus perryi; in Madagascar it occurs in the barbel.

The fish as such does not seem to suffer much from these parasites, which are mainly dormant until the fish is eaten by a human being. The latter is infected in case he fails to apply adequate heat treatment to the fish prior to consumption. In Western Europe this tapeworm seems to be nearly extinct now, owing to good hygiene, which prevents disposal of faeces in fishing waters, on the one hand, and better cooking habits, on the other. The chief center for Diphyllobothrium appears to be around the Gulf of Finland, where it is endemic. Southern Finland shows a prevalence of infection amounting to as much as 20% of the population (Gordon, 1959). A number of Soviet studies from lakes and rivers in adjacent areas, including the Baltic countries, have clearly established this. From these foci they move into the coastal regions of the Baltic Sea. With this ethnic group it has spread to regions chiefly inhabited by the Balts in the United States (Hugghins, 1959).

The fish tapeworm is not infrequently encountered in Alaska and
Greenland (Gordon, 1959). Babero (1951) stated that the incidence of infection was as high as 30% of the native Eskimo population in the Kuskokwim region of southwest Alaska. A new species, *D. alascense*, has recently been described from sledge dogs of the Eskimos (Rausch and Williamson, 1958). Since the natives and their dogs eat the same species of fishes raw, there remains the likelihood that they are harboring the same species.

Related species occur in other parts of the world, such as *D. cordetum* in Greenland and Iceland. Turkestan and Japan are among the countries where *Diphyllobothrium* infections still occur frequently. Occasionally the parasites develop in dogs and cats. Several wild animals, such as foxes, constitute reservoirs.

b. NEMATODA

Several nematodes live as internal parasites in fish. One such example is *Cucullanus elegans*, the larvae of which live in *Cyclops*. The adults, about 5 to 8 mm. long as males and 12 to 18 mm. as females, inhabit the intestines or the eyes. This worm is live-bearing. *Paramermis crassa* in its larval stage lives in red mosquito larvae. *Filaria sanguinea* is found in the fins of crucian carp. In large fish, nematode infections generally do not cause much harm, unless they become numerous. One such infectant is of some economic importance, the nematode *Cystoopsis acipenseris*, specialized on sturgeon (Saidov, 1954). Twelve per cent of *Lophiosilurus alexandri* from the Brazilian São Francisco River harbored nematodes and trematodes (Travassos, 1959).

c. ACANTHOCEPHALA

Parasites from this phylum (popularly called thorny-headed worms) in fish are typical occupants of the intestine. Generally, the larvae live in fresh-water shrimp (*Gammarus pulex*), the water louse (*Asellus aquaticus*), and related crustacea, or in insect larvae. In some species the fish is not the final host, but merely harbors the second larval stage, the final adult stage being reached inside some fish-eating warm-blooded animal. The characteristic feature of the *Acanthocephala* is their protrusible proboscis, bearing a large number of hooks. The body is not membered. The most important genera are *Echinorhynchus*, *Acanthocephalus*, *Co-rynosoma*, *Rhadinorhynchus*, and *Pomphorhynchus*. All are dangerous parasites, producing perforation of the intestines. No cures are known.

d. ANNELIDA

Parasites in this phylum are all found in the class *Hirudinea* (leeches). They are large external parasites with membered bodies and a large sucking disc at each end. The ordinary fish leech *Piscicola geometra*
reaches a length of about 20 to 30 mm., about one inch on the average. Some other genera are Pontobdella, Branchellion, Callobdella, and Cystobranchus. Fish leeches feed on the blood of the fish and may cause considerable harm. They can also be dangerous as transmitters of Trypanoplasma and Trypanosoma species, which cause a sleeping sickness in fish, and of bacterial infections. Removal of leeches has to be done mechanically, by means of forceps (with blunt ends) after the leeches have been paralyzed by a 15-minute treatment with \( \frac{2}{3} \) % sodium chloride solution.

IV. Fish Parasites and Human Food Hygiene

In several countries, e.g., Denmark, Germany, Poland, the Soviet Union, Sweden, the United States, extensive surveys have been made of the occurrence of fish parasites. Particular attention has been devoted to commercially important fishes (Engelbrecht, 1958), such as pike, eel, pike perch, roach, tench, and bream. Detailed lists have been prepared of all categories of fish diseases. Figures could be quoted from all areas of the world indicating the types of infestation—in some regions very heavy and in other areas less. Nevertheless, parasites and diseases are reported from almost everywhere. An essential area of research refers to the transmission of parasites and diseases from one climatic area to another, frequently leading to mass spreading and a change in infective aggressiveness (Reichenbach-Klinke, 1955). This has been discussed in general ecological terms by Cameron (1950) and Szidat (1955-1957).

The most important question with respect to parasites occurring in human food of animal origin is, of course, whether these may threaten human health. With fish as food, the only parasites that are dangerous for man are the tapeworms of the genus Diphyllobothrium, and the liver flukes Haplorchis, Opistorchis, Metorchis, and related genera. Diphyllobothrium may cause heavy anaemia, attributed to some haemolytic substance secreted by the worm and which may be resorbed by the human blood. If the infection is not recognized in time and anthelmintic treatment given, this anaemia may take a fatal course. Infection can be prevented completely if fresh fish is cooked or fried; grilling cannot be relied upon. General prevention lies in the public sphere; good sanitation will prevent the spread of human excreta without disinfection or other cleaning measures into free waters, and dogs and cats must be kept away from fish-breeding ponds.

Several of the red pest bacteria—earlier grouped together under the name of Bacterium murisepticum R. Koch—cause serious skin infections in man. They gain entrance through wounds or scratches and induce inflammations—erysipeloids. Fishermen and employees in fish establishments frequently suffer from this skin trouble (Bandt, 1952-1953).
Other infectious diseases of fish are of minor importance to human beings because they cannot be transmitted, as far as our present knowledge goes. Some may, however, affect human health in a general way by rendering fish unpalatable by enhancing putrefaction and other breakdown pressures. But in principle these defects are not fundamentally different from food spoilage in general.

Exploitation for fish farming encourages human settlements along rivers. This increases the degree of infections in the river, and in turn to a greater degree in the dammed reservoirs. Conditions develop that are particularly favorable for the spread of these infections among human beings according to Soviet studies (Izyumova, 1959).

V. Economic Importance

Few figures are available which assess the economic repercussions of fish diseases, although in fresh waters it is generally easier than in the ocean to obtain an idea of the scope of their ravages. In the artificial raising of fish, one should be able to arrive at concrete figures which closely estimate the losses. As fish cultivation is of major economic importance in few places, such appraisals are, however, not frequently made. It is, nevertheless, known that fish diseases constitute a very real and constant threat to hatcheries, fish-raising establishments, and artificial fish cultivation.

In the United States research on fish diseases is conducted in laboratories of the U.S. Fish and Wildlife Service, the Michigan Institute for Fisheries Research, the Washington State Department of Fisheries, and others.

In the United Kingdom some investigations of limited scope are carried out at certain government laboratories in England and Scotland. In the Netherlands there is no officially organized study of fresh-water fish diseases. Occasionally studies are undertaken by the Nederlandsche Heidemaatschappij, Arnhem. It is natural that the most intense work on diseases of fresh-water fish is done in European countries with valuable resources of rivers, lakes, and ponds.

West Germany is energetically pushing its fight against fish diseases, as well as conducting research in this area (Annual Report of German Fisheries, 1959). The Bavarian Biological Research Institute in Munich is particularly engaged in investigations of fish tuberculosis, and the spreading of new diseases through imported fish. The Institute for Lake Fisheries in Langenargen recently announced the isolation of the virus considered responsible for the kidney swelling of trout (Section III, C). The carp louse is particularly studied in the Pond Research Station in Erlangen.
The inland fisheries of East Germany have their scientific center in Berlin-Friedrichshafen, and a special branch for pond cultivation and fish diseases is located in Wismar. A special carp institute is operating in Königswartha.

In the Soviet Union four major fish research institutions devote a substantial part of their work to the diseases of fresh-water fishes. These are the All-Union Institute for Lake and River fisheries, Moscow (VNIORRCh), the All-Russian Institute for Pond Cultivation, Moscow (RNIPR), the Ukrainian Institute for Inland Fisheries (UNIRCh), and the Moscow Fisheries School (Mosrybwttus). A number of other academies, universities, and biological research centers are also active in this field. A thorough survey has been made to map the occurrence of fish diseases, and it is claimed that great advances have been made in combating these scourges. A comprehensive review of their accomplishments was published in 1955. A special scientific conference in this field was called by the Ichthyological Commission of the Soviet Academy of Science and held in Moscow in 1957. These proceedings were later published (Pavlovskij, 1958).

The Veterinary Institute at Pulawy in Poland is in charge of research and the diagnosis of, and prophylactic measures against, fish diseases. This center is, furthermore, provided with three special laboratories for fish diseases located in different regions of the country (Krakow, Olsztyn, and Wroclaw). The laboratory in Olsztyn, close to the Masurian marsh area, devotes its attention primarily to lake fisheries; the others serve chiefly fish-raising pond establishments (Kocylowski, 1958).

REFERENCES

Babero. (1951).
16. DISEASES OF FRESH-WATER FISH


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